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Utilization Potential of Extractives from Naturally Durable Timber Species, *Tectona grandis* (Lin f.), *Xylia xylocarpus* (Roxb.) and *Pterocarpus macrocarpus* (Kutz.) as Natural Wood Preservatives

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Utilization Potential of Extractives from Naturally Durable Timber Species, *Tectona grandis (*Lin f.), ***Xylia xylocarpus* (Roxb.) and *Pterocarpus macrocarpus* (Kruz) as Natural Wood Preservatives**

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Abstract

To avoid the use of toxic synthetic chemicals due to their potential environmental impacts, the feasibility of using heartwood extracts from *naturally durable wood* as wood preservatives against the subterranean termite was investigated in laboratory experiments. The sawdust of *Tectona grandis*, *Xylia xylocarpus* and *Pterocarpus macrocarpus* was extracted using methanol and ethyl ether solvents. Heartwood blocks (20 × 20 × 20 mm - sized) of three non-durable wood species, In, Kanyin and Pine were impregnated with the extractives. The resistance of termite attack was evaluated above-ground method. Results of the tests showed significant weight loss from termite feeding on wood samples treated with extractives compared with untreated wood samples for all wood species. According to the virtual rating, control wood samples (untreated) were totally destroyed by termites and the wood samples treated with extractives were remained almost unchanged. Results of the current study indicated that the heartwood extractives of tested wood species have potential to be used as environmentally friendly wood preservatives.

Keywords: Extractives, Durability, Preservative, Termiticide

သဘာဝအလျှောက် ကြာရှည်ခံနိုင်သည့်သစ်မျိုးများဖြစ်သည့် ကျွန်း၊ ပျဉ်းကတိုး၊ ပိတောက် တို့မှ ထုတ်ယူထားသည့် Extractives များအား သစ်ကြာရှည်ခံဆေးအဖြစ် အသုံးပြုနိုင်မှု အလားအလာကို လေ့လာဖော်ထုတ်ခြင်း

ချိုချိုဝင်း၊ သုတေသနအရာရှိ
သစ်တောသုတေသနဌာန၊ သစ်တောဦးစီးဌာန

စာတမ်းအကျဉ်း

သစ်ကြာရှည်ခံဆေးများသည် သဘာဝပတ်ဝန်းကျင်အား ထိခိုက်လာသဖြင့် အသုံးမပြုရန် ကန့်သတ်ချက်များထားရှိလာသောကြောင့် Wood extractives များကို ခြစားမှုဒဏ် နှင့် သစ်ဆွေးမှိုဒဏ်ကို ကာကွယ်ရာတွင်အသုံးပြုနိုင်ရန် ကမ္ဘာနှင့်အဝှမ်းတွင် စမ်းသပ်မှုများ ပြုလုပ်လာကြပါသည်။ ကျွန်း၊ ပျဉ်းကတိုး၊ ပိတောက်၊ စသည့်သစ်မျိုးများသည် ခြစားမှု ဒဏ်ကို ကောင်းစွာခံနိုင်ရည်ရှိကြောင်း၊ ဓာတုဒြပ်ပေါင်းပါဝင်မှု စမ်းသပ်ချက်များအရလည်း ကျွန်း၏ အနှစ်သားတွင် ခြစားမှုကိုကာကွယ်နိုင်သည့် အင်သရာကွီနုန်းကဲ့သို့သော ဓာတုဒြပ် ပေါင်းများ ပါဝင်ကြောင်း၊ ပျဉ်းကတိုးနှင့် ပိတောက်တို့၏ အနှစ်သားတွင်လည်း ခြစားမှုကိုခံ နိုင်သည့် Flavanoid ဒြပ်ပေါင်းနှင့် Phenol ဒြပ်ပေါင်းများပါဝင်ကြောင်း ကနဦး စမ်းသပ်ချက် များအရ သိရှိထားပါသည်။ ဤသုတေသနစာတမ်းတွင် ကျွန်း၊ ပျဉ်းကတိုး နှင့် ပိတောက် လွှစာမှုန့်များကို organic solvent များဖြစ်သည့် Methyl ethanol နှင့် Ethyl Ether တို့ကို အသုံးပြု၍ သဘာဝအလျှောက် ပါဝင်နေသော Extractives များကိုထုတ်ယူပြီး ခြစားမှုကို ခံနိုင်ရည် စွမ်းမရှိသည့် အင်၊ ကညင် နှင့် ထင်းရှူး သစ်များကို ရရှိလာသော extract များဖြင့် ဆေးသွင်း ပြုပြင်ပါသည်။ ထို့နောက် ခြစားမှုဒဏ်ခံနိုင်စွမ်းကို မြေမြှုပ်စမ်းသပ်နည်း (under -ground method) ဖြင့် စမ်းသပ်ခဲ့ပါသည်။ တွေ့ရှိချက်များအရ ကျွန်း၊ ပျဉ်းကတိုးနှင့် ပိတောက်တို့မှ ထုတ်ယူရရှိသည့် Extractives များဖြင့် ဆေးသွင်းပြုပြင်ထားသည့် အင်၊ ကညင် နှင့် ထင်းရှူး သစ်နမူနာများသည် ခြစားမှုဒဏ်ကို ခံနိုင်ပြီး အလေးချိန်လျော့ကျမှု နည်းကြောင်း တွေ့ရှိရပါ သည်။ သို့ဖြစ်ပါ၍ ကျွန်း၊ ပျဉ်းကတိုးနှင့် ပိတောက်တို့မှ ထုတ်ယူရရှိသည့် Extractives များသည် ခြစားမှုကိုကာကွယ်နိုင်သည့် သစ်ကြာရှည်ခံဆေးအဖြစ်သုံးရန် အလားအလာ ရှိကြောင်း တွေ့ရှိရပါသည်။

Utilization Potential of Extractives from Naturally Durable Timber Species, *Tectona grandis (*Lin f.), *Xyliaxylocarpus* (Roxb.) and *Pterocarpus macrocarpus* (Kruz) as Natural Wood Preservatives

1. Introduction

Myanmar is a tropical country with a wide range of climates and soils. So, Myanmar has different types of forest and its associates. According to Forest Resource Assessment (FRA, 2015), Myanmar is endowed with high forest cover of 42.92% of the country's total area which consists of hundreds of timber producing tree species. Although there are about 2088 tree species (1345 big trees and 742 small trees) in Myanmar, only 88 species are produced multipurpose timber of high quality (FD, 2000). Among these species, Teak (*Tectona grandis*) is famous world- wide and constitutes one of the most valuable resources of the nation. There are few more commercially acceptable species both domestic and abroad trade such as Pyinkado (*Xyliaxyllocarpa*), Padauk (*Pterocarpus macrocarpus*), Thitya-Ingyin (*Shorea*spp:) and decorative species such as Tamalan (*Dalbergia oliveri*), Thinwin (*Millettiapendula*), Hnaw (*Adina cordifolia*) and Taung-thayet (*Swintonia floribunda*) (WinKyi -1 et al, 1993).Many of the rest are being lesser- used timber species (LUS).

Effective utilization of wood depends on strength, durability, beauty and availability of species. Many LUS have good utilization potential (Win Kyi -1 et al, 1993). But a basic problem has been indicated that the LUS have a bad reputation because of poor durability. Most of the LUS are not durable and susceptible to the attack of fungi and termites. If this non-durability could be reduced, the chance of commercial acceptance would be much improved (Win Kyi – 2, 1995).

Preservative treatment of wood using toxic chemicals has a long history throughout the world. However, some reports indicate that creosote is carcinogenic (Karlehazen, 1990), arsenic leach out of the treated wood and pollutes soils and waters (Bergholm, 1990; Garcia & Rowland, 2001; Solo-Gabriele et al, 1998; 2000; 2002) and chromium produces dermal inhalation diseases (Chen et al, 2001). Therefore, the use of these preservatives is being subjected to decrease and some of them (eg. CCA) are going to bebanded.

One goal of the wood preservation industry became to exploit natural defense mechanisms to prevent environmental degradation. Wood extractives play a major role in the protection of wood against termite and fungal attack. Wood extractives are naturally formed in trees and may be environmentally friendly after application.

In this study, to avoid the use of toxic synthetic chemicals due to their potential environmental impacts, the feasibility of using durable heartwood extracts from Teak (*Tectona grandis*), Pyinkado (*Xyliaxylocarpus*) and Padauk (*Pterocarpus macrocarpus*)as wood preservatives against the subterranean termite was investigated.

2. Objectives

The objectives of the study are-

(1) to observe the effect of extract from *Tectona randis*, *Xyliaxylocarpus* and *Pterocarpus macrocarpus*against termitesattack and

(2) to investigate the effects of different solvent extractions from those species on some non-durable timber species, *Dipterocarpus tuberculatus*(In) ,*D. terbinatus* (Kanyin) and *Pinus spp*. (Tinyu) using wood extracts.

3. Literature Reviews

3.1 Role of Extractives in Wood Durability

Evaluation of natural termite resistance in tropical species is becoming increasingly important in the wood preservation industry. Tsunoda, (1990) indicate that certain tropical wood species are resistant to termite attack and could be effective substitutes for pressure-treated lumber.

According to W.P.K. Findley(1985), *Tectona grandis* (Teak), *Adina cordifolia* (Hnaw), *Albizia procera* (Sit), *Cedrela toona* (Thitkado), *Dalbergia latifolia*, *Hopia odorata* (Thingan), *Pterocarpus indicus* and *Shorea* (certain spp) are naturally durable species in the region of India, Myanmar and Malaysia.Win Kyi-2 (2006) observed and stated that Gangaw, Thitya, Ingyin, Padauk, Pyinkado, Taukkyan and Thitkha were resistant to termite. Aung Soe& Cho Cho Win (2006) stated that *Thitpayaung* and *Taungpeinne* were termite resistant after 5 years Graveyard test.

A number of factors influence the durability of a timber, including wood density, tree age, and growing location. However, the most important factor is the extractives within the heartwood of wood.Wood extractives are one of the main reasons for the resistance of wood to termite attack (Balfas, J. 2019).

Several researches of the relationship between extractives and natural durability of wood were examined (Hawley et al, 1924; Scheffer and Cowling 1966; Carter et al, 1978; Hillis 1987; McDaniel 1992; Taylor 2006; Santana et al, 2010). Cho Cho Win (2017) studied the termite resistant Myanmar timber species using underground method and *Teak, Pyinkado, Padauk, Htaukkyan, Thingan, Ingyin, Taungpetwun, thitkha, Thitpayaung, Panga, Zaungbale, Leza, Gyo and Hnaw*were resistant to termite attack and the effective chemical compound to be resistant against termite were also studied.

Teak (*Tectona grandis*) is a valuable wood with high durability and very resistant to termite attack. Teak heartwood contains a number of toxic extractives (Rudman and Dacosta, 1959; Hillis, 1987; Thevenon*et al*. 2001) and Tectoquinone, a potent insecticide extractive found in teak, is highly repellent to the dry-wood termite (Wolcott, 1955) and to the subterranean-termite (Sandermann and Dietrichs, 1957). Haupt *et al*. (2003) also evaluated the role of tectoquinone in relation to durability and Tectoquinone yield was high in specimens with high natural durability. Myo Aung (1988) found five anthraquinone extractives identified by HPLC. The most abundant compound in teak methanol extract was 2-methyl anthraquinone. The naphthoquinone plays a key role in the resistance of teak against fungi attack (Niamké et al, 2012) and Tectoquinone, anthraquinone presented strong antitermitic activity (Haupt et al, 2003; Kokutse et al, 2006).

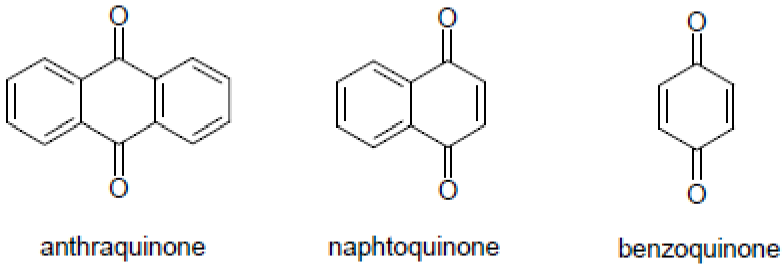

Figure 3.1 Structure of anthraquinone, naphtoquinone and benzoquinone

Pyinkado (*Xylia xylocarpa* Roxb.) common name, Iron wood is one of the most famous hardwoods used for construction. It belongs to the family *Leguminosae* and subfamily *Mimosoideae*. The heartwood is reddish brown with darker streaks, sapwood is pale reddish white. The durability of heartwood is rated as very durable and rarely attacked by termites. Pattarawadee Sumthong Nakmee et al., (2016) reported that the crude extract of saw dust from *X. xylocarpa* (Roxb.) displayed antimicrobial activity and might be used for surface coating of softwood materials and composite woods.

Padauk (*Pterocarpus macrocarpus*Kurz.) common name, Rose wood, has higher density and the wood is extremely durable and resistant to termites and other insects (Designing Building, 2020). By GC–MS analysis, there are 17 kinds of chemical components in the *P.Macrocarpus* extract. Morimoto et al, 2006 studied the antifeedant activities of three pterocarpans against the subterranean termite and the most active antifeedant was (-)-homopterocarpin. However, all pterocarpans showed antifeedant activity against termite.

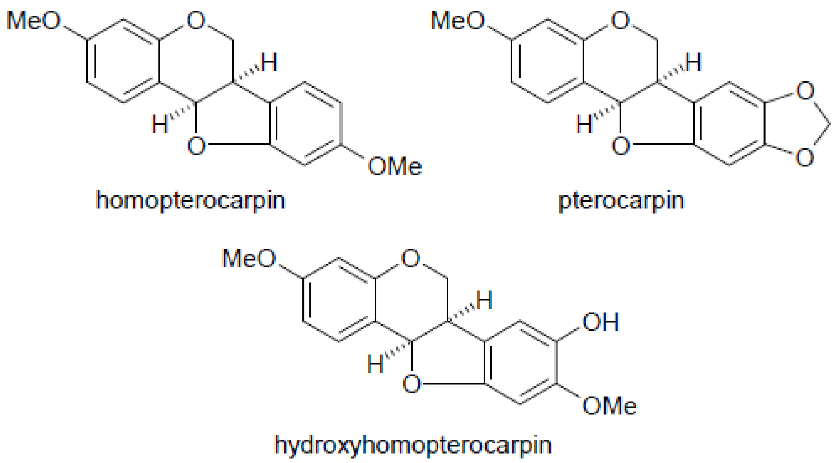

Figure 3.2 Structure of homopterocarpin, pterocarpin and hydrohomopterocarpin

3.2 Testing the Termite Resistance

Traditionally, field test methods for determining the efficacy of wood preservatives against termites involved large scale outdoor field trials of poles or stakes. Trails of this type can take between five to ten years for stakes (Ruddick, 1989) and upwards to twenty years for poles to yield any meaningful results. As a result a need for a more rapid, interim evaluation of the regimes and chemicals tested became apparent (Desch and Dinwoodie, 1981; Johnson et al, 1982).

Internationally, various accelerated test methods, including laboratory and fieldexposure tests, have been developed over the years to determine the performance of treatedwood samples in the presence of decay fungi (Smith and Byrne, 1985; Johnson et al, 1983; Hedley, 1978) or termites (Thornton et al, 1983; Preston et al, 1985; Johnson and Thornton, 1991; Lenz et al., 1992; Creffield, 1994) with varying degrees of success.

Field trials were preferred to laboratory studies because they allow the collective and cumulative effects of all kinds of abiotic and biotic deterioration factors to be evaluated (Peralta *et al.* 2003). They also give reliable data regarding natural resistance of wood (Bultman and Southwell 1976).

4. Materials and Methods

4.1. Extraction of Durable Species

The saw-dustwere prepared from Authenticated wood sample of Teak, Pyinkado and Padauk. The sawdust samples were extracted using 98% Methanol solvent and 98% Ethyl Ether solvent. Two hundred grams of the samples of each selected saw-dustwere extracted with solvent solution such as 150ml of Methanol, and 150distilled waterand 150ml of Ethylether, and 150 distilled water respectively. A total of 6 wood extracts (three wood species and 2 solvents) were obtained. During percolation, the crude mixture was frequently shaken to achieve the maximum extraction. The extracts were filtered using Whatman number-1 filter paper. The extract was evaporated and the extract were weight to know the extract gained.

4.2 Sample Collection andPreparation

The wood of *Pinnus spp.*is relatively soft and light and very susceptible to termite. Therefore, most of the methods for laboratory evaluation of solid wood against termite, pine wood block was used as control. The wood of *Dipterocarpus tuberculatusand D. turbinatus* are strong enough to use in structural applications. It is moderately resistant to decay, but not resistant to termites. It is well known to be very susceptible to termite attack, the sapwood being more susceptible than the heartwood.

Therefore, low durability and termite susceptible wood of In (*Dipterocarpus tuberculatus.* Roxb), Kanyin *(D. turbinatus) and Tinyu (Pinnus spp.*) were selected to test for the effectiveness of the extracts in the study

Sample preparation was carried out at Saw-mill of Forest Research Institute, Yezin. The outer heartwoods of tested wood species were .planed and cut into small test specimens of 20mm x 20mm x 20mm blocks. 100 specimens were used for each species. 10 samples were used for moisture content (MC %) calculation. Ten replications were selected for each extract. These blocks were free from knots, drying defects and without visible evidence of fungus infection.

4.3. Treatment of Samples with Extracts

Ten test specimens of each of the three less durable timber species in the study were randomly selected from the samples and treated with Methanol and Ethylether extracts from *T. grandis, X. xolocarpa* and *P. macrocarpus.* As a control, ten specimens of each less durable species were tested to the termites without any treatment. Treatment involved total immersion of the specimens in a bath of extracts for 5 days until a constant weight was achieved. After treatment, all the test blocks were conditioned by oven-drying for 48 hours at 60ºC and weighed periodically until constant weights were attained. These test blocks were used for the field test.

4.4 Laboratory Termite Resistance Test

A test site at FRI, highly susceptible to subterranean termites was chosen for study. The design of the field test procedure is as follows: a ditch of consistently 15-20 cm depth is dug and filled with the residues from coconut fibers and susceptible wood veneers (to bait and aggregate termites). After two weeks later, the bait veneers were covered with termites. The site was ready to test.

Wood blocks were placed above the residue layer and additional amounts of residues added to conceal the blocks, and the ground covered with top soil. The test specimens were labeled and end painted with different colors for easy identification (Bultman and Southwell 1976) and then exposed to termites in the field. The places and positions of the test blocks were noted in the record book to easily know after test period.

After 16 weeks, the specimens were removed from the tested sites and cleaned up. The ground was unearthed, the blocks carefully retrieved, weighed immediately to determine the final wet weight and then oven dried. Determinations the moisture content (%) of final block and percentage mass loss (%) were carried out. Then these final mass of specimens were weighed after 48 hour at 60°C in oven by the same way of determination of initial mass.

The test blocks were also rated according to an arbitrary 0-5 visual scale as: 0 = sound, l = surface, 2 = light attack, 3 = moderate attack with bore holes, 4 = heavy/severe attack and 5 = completely destroyed. The grading by mass loss of specimen was corrected by visual observation.On the basis of the percentage of wood eaten (weight loss in percent) by termites during the test period, the termite resistance of tested wood species were grouped into the following various resistance classes (P.K. SEN-SARMA, 1975).

Table 4.1 Classification of Termite Resistant Based on Weight Loss (%)

Percentage of weight loss of tested wood	Termite Resistance Class
0-6	Very Resistant (Class I)
7-10	Resistant (Class II)
11-14	Moderately Resistant (Class III)
15-17	Poorly Resistant (Class IV+)
Above 17	Perishable (Class V-)

Source: P.K. SEN-SARMA, 1975

4.5. Statistical Analysis

The data recorded were mean weight loss percentage of individual species. The data obtained were statically analyzed using ANOVA (Analysis of Variance), following a Randomized Complete Block Design (RCBD). Mean comparison of treatments was done by using Least Significant Difference Test (LSD).

5. Results and Discussion

5.1. Effect of Wood Extractives on Termite Resistance of In

Thetermite resistance of (*D. tuberculatus*) and effectiveness of wood extractives from durable species (Teak, Pyinkado and Padauk) was shown in Table (5.1). Average weight loss for untreated In (control) was 11.42%. According to the Termite Resistant classification, D. *tuberculatus* lies into moderately resistant.

The average weight loss for *D. tuberculatus* treated with Teak methyl extractive and ethylether extractive were 0.29 % and 0.97 % respectively after exposure to termite attack. Average weight loss for *D. tuberculatus* treated with Pyinkado methyl extractive and ethylether extractive was 5.10 % and 3.03% respectively and average weight loss for *D. tuberculatus* treated with Padauk methyl extractive and ethylether extractive was 1.36 % and 1.43% respectively after exposure to termite attack. This indicates that resistance to termite attack of *D. tuberculatus* was significantly improved after treatment with extractives. Tested wood extractives may be effective on the termite resistant of this species.

Analysis of variance shows that the resistance to termite attacks of In increased significantly after treatment with wood extractives. A pair comparison of means using the Least Significant Difference (LSD) statistical test shows that there is significant difference using Pyinkado methyl extractive and Pyinkado ethyl-ether extractives.

Table 5.1 The Effectiveness of Wood Extractives on In wood samples

Treatment	*Count*	*Sum*	*Average*	*Variance*
Control	10	114.18	11.42	9.02
Teak Methanol extract	10	2.90	0.29	0.13
Teak Ethylether extract	10	9.71	0.97	1.96
Pyinkado Methanol extract	10	50.98	5.10	4.31
Pyinkado Ethylether extract	10	30.30	3.03	5.46
Pyinkado Methanol extract	10	13.61	1.36	1.64
Pyinkado Ethylether extract	10	14.28	1.43	3.99

Table 5.2 ANOVA for the resistance to termite attacks of In

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Replication	11.19681	9	1.24409	0.295458	0.973035	2.05852
Treatment	909.2093	6	151.5349	35.98798	1.15E-17	2.271989
Error	227.3783	54	4.210708			
Total	1147.784	69				

Table 5.3 Mean Comparisonfor the resistance to termite attacks of In

	Control	TM	TE	PKM	PKE	PDM	PDE
Control	0	11.128*	10.447*	6.32*	8.388*	10.057*	9.99*
TM		0	1.029	-4.808	-2.74	-1.071	-1.138
TE			0	-4.127	-2.059	-0.39	-0.457
PKM				0	2.068*	3.737*	3.67*
PKE					0	1.669*	1.602*
PDM						0	-0.067
PDE		LSD	1.84				0

*significant at 0.05 level

5.2. Effect of Wood Extractives on Termite Resistance of Kanyin

Thetermite resistance of Kanyin (*D. turbinatus*) and effectiveness of using wood extractives from durable species (Teak, Pyinkado and Padauk) was shown in Table (5.4). The average weight loss for untreated Kanyin (*D. turbinatus*) was 13.10%. According to the Termite Resistant Classification, it can be said that Kanyin wood samples were moderately resistance (MR).

Average weight loss for *D. tuberculatus* treated with Teak Methyl extractive and Ethylether extractive was 2.90 % and 1.43 % respectively after exposure to termite attack. Average weight loss for *D. tuberculatus* treated with Pyinkado Methyl extractive and Ethylether extractive was 3.04 % and 3.16% respectively after exposure to termite attack. Average weight loss for *D. tuberculatus* treated with Padauk Methyl extractive and Ethylether extractive was 1.02 % and 1.40 % respectively after exposure to termite attack.

In table (5.4) Analysis of variance shows that the termite resistance of Kanyin increased significantly after treatment with wood extractives. A pair comparison of means using the Least Significant Difference (LSD) statistical test shows that there is significant difference using Pyinkado methyl extractive and Pyinkado ethyl-ether extractives.

Table 5.4 Termite Resistance of Kanyin

Treatment	*Count*	*Sum*	*Average*	*Variance*
Control	10	130.99	13.10	4.16
Teak Methanol extract	10	28.15	2.82	1.60
Teak Ethylether extract	10	14.27	1.43	4.50
Pyinkado Methanol extract	10	30.37	3.04	4.33
Pyinkado Ethylether extract	10	31.64	3.16	1.59
Pyinkado Methanol extract	10	10.18	1.02	1.17
Pyinkado Ethylether extract	10	13.97	1.40	2.25

Table 5.5 ANOVA for the resistance to termite attacks of Kanyin

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Replication	3.4249	9	0.3805	0.1187	0.9991	2.0585
Treatment	1075.1430	6	179.1905	55.9083	2.07E-	2.2720
Error	173.0741	54	3.2051			
Total	1251.6420	69				

Table 5.6 Mean Comparison for the resistance to termite attacks of Kanyin

	Control	TM	TE	PKM	PKE	PDM	PDE
Control	0.00	10.28*	11.67*	10.06*	9.94*	12.08*	11.70*
TM		0.00	0.57	-0.22	-0.35	1.80*	1.42
TE			0.00	-1.61	-1.74	0.41	0.03
PKM				0.00	-0.13	2.02*	1.64*
PKE					0.00	2.15*	1.77*
PDM						0.00	-0.38
PDE		LSD	1.6				0.00

*significant at 0.05 level

5.3 Effect of Wood Extractives on Termite Resistance of Tinyu

Thetermite resistance and effectiveness of Tinyu (*Pinus spp.*) using wood extractives from durable species (Teak, Pyinkado and Padauk) was shown in Table (5.7). The average weight loss of untreated Tinyu was 21.19%. According to the Termite Resistant Classification, it can be said that Tinyu wood was Perishable (P).

Average weight loss for *Tinyu* treated with Teak Methyl extractive and Ethylether extractive was 1.44 % and 0.42 % respectively after exposure to termite attack. Average weight loss for *Tinyu* treated with Pyinkado Methyl extractive and Ethylether extractive was 3.14 % and 2.24 % respectively after exposure to termite attack. Average weight loss for *Tinyu* treated with Padauk Methyl extractive and Ethylether extractive was 2.75 % and 3.86 % respectively after exposure to termite attack. Their resistance to termite attack significantly improved after treatment with extractives and durability class improved to Resistant and very resistant.

Analysis of variance shows that the resistance to termite attack of *Tinyu* increased significantly after treatment with wood extractives. The mean difference is significant at the 0.05 level. A pair comparison of means using the Least Significant Difference (LSD) statistical test shows that there is no significant difference between treatments.

Table 5.7 Termite Resistance of Tinyu

Treatment	*Count*	*Sum*	*Average*	*Variance*
Control	10	211.93	21.193	148.5517
Teak Methanol extract	10	14.37	1.437	1.409534
Teak Ethylether extract	10	4.24	0.424	0.265516
Pyinkado Methanol extract	10	31.40	3.140	8.330911
Pyinkado Ethylether extract	10	22.43	2.243	2.621579
Padauk Methanol extract	10	27.47	2.747	7.239757
Padauk Ethylether extract	10	38.64	3.864	9.701782

Table 5.8 ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Replication	264.8535	9	29.42816	1.187477	0.321844	2.05852
Treatment	3132.748	6	522.1247	21.06862	1.47E-12	2.271989
Error	1338.233	54	24.7821			
Total	4735.835	69				

Table 5.9 Mean Comparison for the resistance to termite attacks of Tinyu

	Control	TM	TE	PKM	PKE	PDM	PDE
Control	0.00	19.76*	20.77*	18.05*	18.95*	18.45*	17.33*
TM		0.00	1.58	-1.70	-0.81	-1.31	-2.43
TE			0.00	-2.72	-1.82	-2.32	-3.44
PKM				0.00	0.90	0.39	-0.72
PKE					0.00	-0.50	-1.62
PDM						0.00	-1.12
PDE		LSD	4.45				0.00

*significant at 0.05 level

5.4 Termite Resistance of Tested Species

The weight losses of tested wood species with respective treatments were shown in Table (5.10). In order to clearly reveal the difference not only between the weight losses of untreated and treated blocks, but also between species, statistical analysis was also carried out using Two-Way ANOVA with replication. Mean weight losses against the extraction solutions are shown graphically in Figures (5.1).

According to ANOVA analysis, the mean weight losses of extractive treated wood samples are significantly decreased that of controls for all species. It means that treatments by extractive were found to be highly significant ($P<0.01$, $F=16.03$). This is probably because different solvents extracted different compounds from the durable woods that later improved the less durable wood species. However, there is no significant difference among the species.

Chemical combinations of the several wood extractives could probably be the reason for the improvement of resistance to termites. Different compounds obtained by the different extracting solvents show different efficacy towards termite resistance. Since there are many different compounds present in wood extractives, it was not possible to determine the active chemicals that are toxic to termites.

Table 5.10 Termite Resistance of Tested Species

Species	Control	TM	TE	PKM	PKE	PDM	PDE
In	11.42	0.29	0.97	5.10	3.03	1.36	1.43
Kanyin	13.10	2.82	1.43	3.04	3.16	1.02	1.40
Tinyu	21.19	1.44	0.42	3.14	2.24	2.75	3.86

Table 5.10 Termite Resistance of Tested Species

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Species	10.44614	2	5.223069	1.104237	0.362913	3.885294
Treatments	454.9497	6	75.82495	16.03055	4.27E-05	2.99612
Error	56.76032	12	4.730027			
Total	522.1562	20				

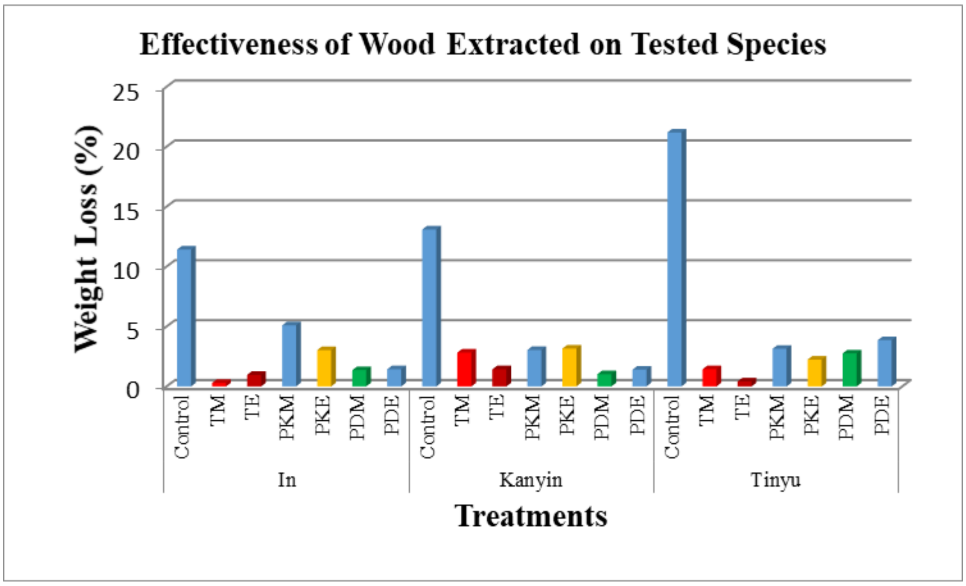

Figure 5.1 Effectiveness of Wood Extracted on Tested Species

5.5 Retention of Extractive Absorbed by the Tested Species

Results of the experiments were evaluated as average extractive retention (%) of individual species. Average retention of tested species immersion in six different solvent solutions are shown in Table 5.11.In order to clearly reveal the difference between treatments, statistical analysis was also carried out by using Two-Way ANOVA without replication. The mean retention of extractive solutions by each wood species are also shown graphically in Figures (5.2).

The concentration of extractives varies among species. According to ANOVA, are found to be significant among the species but there is no significantly difference among the extractives. Factors affecting wood consumption by termites and fungi are numerous and complexly related. The amount however can vary from season to season even in the same tissue or are restricted in certain wood species (Taylor et al, 2006).

Table 5.11 Mean Retention of Extractives

Species	Control	TM	TE	PKM	PKE	PDM	PDE
In		15.39	13.53	13.08	12.51	11.83	10.64
Kanyin		17.32	13.79	13.94	19.40	13.62	16.90
Tinyu		21.30	14.48	16.72	24.14	15.60	16.23

Table 5.12 Analysis of Variance for Extractive Retention

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	83.19501	2	41.5975	9.944358	0.004192	4.102821
Columns	71.37651	5	14.2753	3.412674	0.046617	3.325835
Error	41.83026	10	4.18303			
Total	196.4018	17				

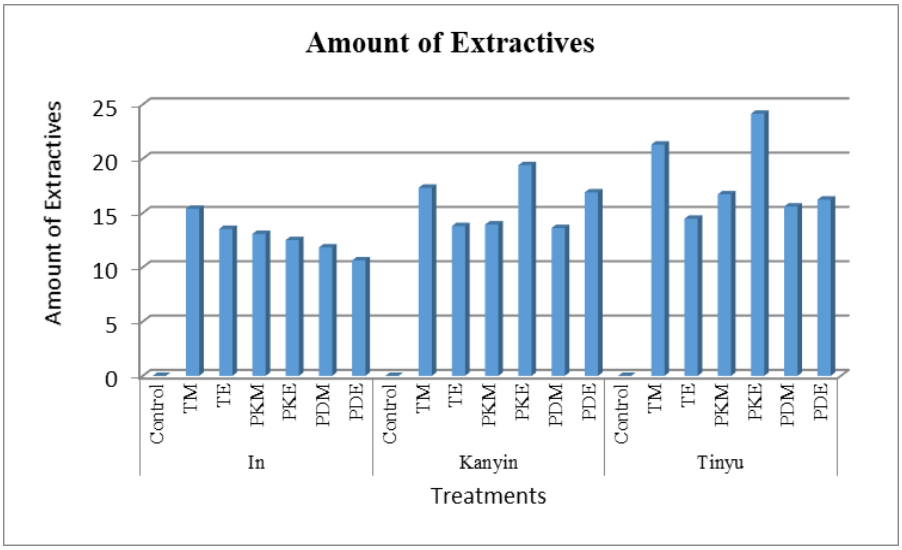

Figure 5.2 Mean retention of extractive

5.6. Relationship between Extractives and Weight Loss by Termite

Weight loss determination showed that treatment by extractives from durable wood species provides a considerable bio-resistance for all species. In order to clearly reveal the correlation between extractive retention and the weight losses of treated samples, statistical analysis was made by using simple linear regression method and the results obtained are given in Table (5.13). According to this table, it was clearly indicated that weight loss (%) of tested species were highly correlated to extractive retention at 0.01∝ - level by the given equations in that table. The relationship between extractive retention and weight loss for the tested species are shown in Figure (5.3), (5.4) and (5.5).

Table 5.13 Relationship between Mean extractive Retention and weight loss (%)

Species	Number of samples	Correlation coefficient (r^2)	Regression equation	*P* (%)
D. tuberculatus	7	0.802	Y= -0.688x + 10.93	0.52771
D. turbinatus	7	0.776	Y= -0.585x + 11.65	0.7105
Pinus spp	7	0.785	Y= -0.836x + 17.96	0.5368

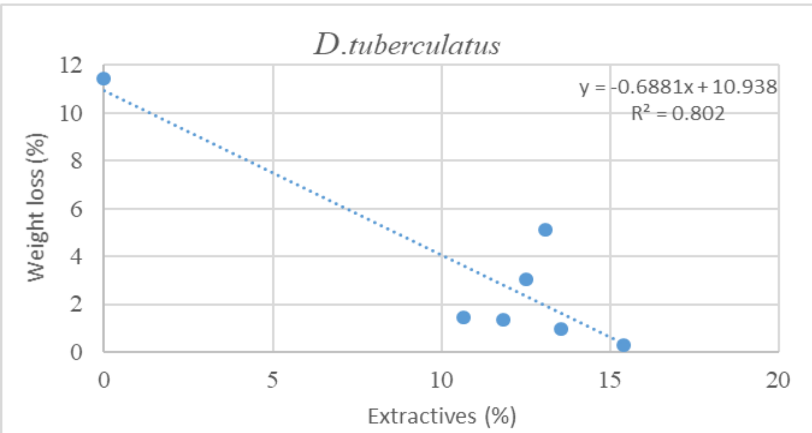

Figure 5.3 Relationship between extractive retention and weight loss for *D. tuberculatus*

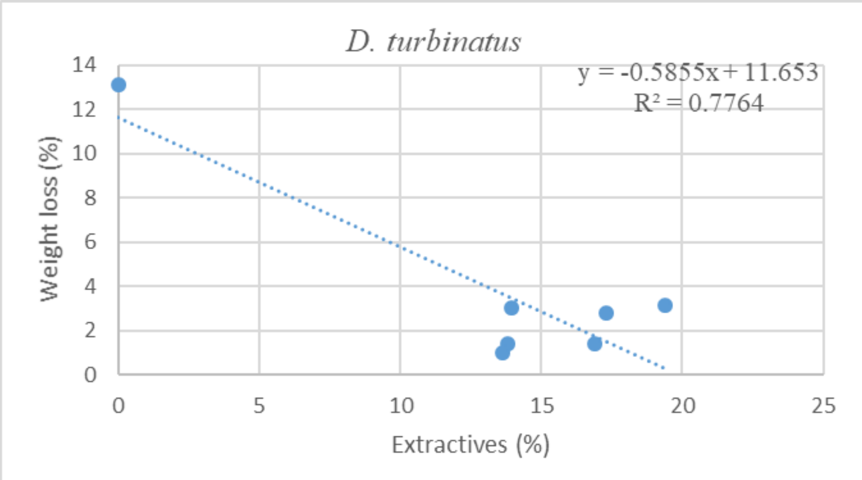

Figure 5.4 Relationship between extractive retention and weight loss for *D.turbinatus*

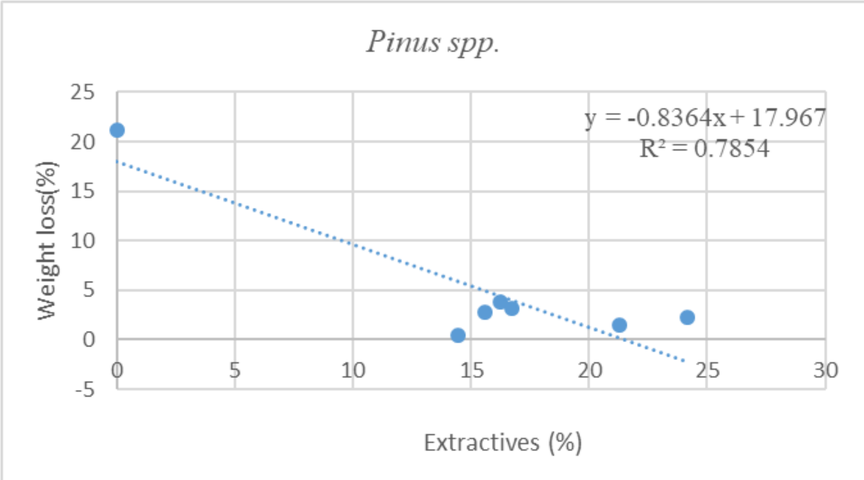

Figure 5.5 Relationship between extractive retention and weight loss for *Pinun spp.*

5.7. Visual assessment for Termite Resistant Test

According to the visual assessment, the wood blocks of untreated In (*D. tuberculatus*) and Kanyin (*D. turbinatus*) were severely destroyed and 50% of the wood blocks were completely eaten by termites after 16 weeks exposure in the ground. This indicates that the wood species are susceptible to attack by termites and they are moderately resistant.

For the most susceptible species, Tinyu (*Pinus spp*.), it was found that most of the replicates had completely eaten and visual rating marked as 4 after sixteen weeks exposure. Therefore, tested Pinus spp. was found to be perishable.

However, the wood samples treated with different extractives were remained sound in the same period of exposure and their resistance to termite attack was significantly improved to very resistant. It can be seen that the resistance to termite attack was significantly improved after treatment with extractives in figure (5.6) and (5.7).

Therefore, it can be said that extractives were effective for those wood species.

Figure 5.6 Photo show termite attack for untreated wood samples.

Figure 5.7 Photo show termite attack for untreated wood samples.

Figure 5.8 Photo show termite attack for Extracted treated wood samples.

5.8 General Discussion

Weight losses for all extractive treated samples decreased significantly confirming the effectiveness of extract solution in enhancing termite resistance. Wood extractives were found to increase resistance to termite attack in both *D. tuberculatus* and *D. turbinatus* by 5 times to 10 times. In the case of *Pinus spp*., it was increased to 50%. Similar results were reported by Goktas *et al.* (2007) who evaluated the wood preservative potentials of some extracts.

Resistance of these woods to termites after treatment could be due to the extractive's repellent characteristics. The repellent characteristics could be due to the toxic chemical composition of the various wood extractives and the durability of the heartwood of the tree species from which they were extracted. Taylor *et al.* (2006) also concluded that it was not possible to focus on a single heartwood extractive measurement in order to understand the natural durability but on their combination.

Kirker et al. (2013) studied the protective role of extractives in high durable wood species from North America and the individual active compounds of wood extractives confer the durability also discovered. The obtained results showed a relationship between extractives content and resistance against wood decaying fungi but not with the quantity of extractives.

Besides wood extractive, chemical components such as cellulose, lignin and total phenolic content of wood showed influence on the rate of degradation. The higher cellulose content, the less resistance to termite attacked and the higher lignin and total phenolic content, the more resistance of the wood against termite attack.

In 1984, Preservation of In (*D. tuberculatus*) by using vacuum-pressure impregnation technique with Tanalith- C was carried out at No. (75) Sawmill, O-Bo-Taung, Monywa Township, Sagaing Division. Treatability of In (*D. tuberculatus*) with CCA water borne preservatives using vacuum pressure process were carried out by Win Kyi -2 (1988) and showed very poor in penetration. The treatability and performance of In (*D. tuberculatus)* was tested by Austen Nyunt (1988) and he also reported that it was quite refractory in vacuum pressure treatment. Therefore, dipping method was used in this study.

Lwin and Cho (2012) studied the termite resistance of *D. tuberculatus* treated by different wood preservatives and it was found that the weight loss of 7.58% for Polybor treated *D. tuberculatus*, 3.81% for treatment by Boric acid and Borax mixture and 3.6% for Acetylated *D. tuberculatus* respectively.

According to Austen Nyunt (1988) it found that the weight loss of CCA treated *D. tuberculatus* were 5.12% , 3.97%, 3.84%, 3.23% and for CCA concentration of 0.76%, 1.5%, 3.24%, 4.54% and 7.57% respectively.

Therefore, it can be said that to increase the termite resistance, treatment with extractives was more effective than treatment with CCA, Polybor and Boric acid and Borax mixture.

However, some author reported that the susceptible timbers treated with were treated Extractives would not offer a practical alternative to CCA treatment. It is important to understand the specific extractives which effective to protect the wood against termite attack. Taylor *et al.* (2006) also concluded that it was not possible to focus on a single heartwood extractive measurement in order to understand the natural durability. It was recommended that to use the combination of different extractives from various durable woods.

In my research, the higher resistance could be achieved by using combination of different extractives from durable timbers as a source of extractives. This is because different compounds obtained by the different extracting solvents show different efficacy towards termite resistance. Since there are many different compounds present in wood extractives, it was not possible to determine the active chemicals that are toxic to termites.

6. Conclusion and Recommendation

This study showed that termite resistance of perishable *Pinus spp*. and moderately resistant wood species, *D. tuberculatus* and *D. turbinatus* were significantly increased after treatment with extracts from durable tree species. Therefore, it can be said that all of the extractives from this study possess enough antitermite properties and they have utilization potential to control the termite.

Hence, strong recommendations are being made to develop eco-friendly antitermite formulation from Teak extractive and Padauk extractives for effective control of field termites.

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